Docket No. SA-537

Exhibit No. 14-A

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Human Performance

Factual Report of Group Chairman

(17)

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

November 26, 2013

HUMAN PERFORMANCE

Group Chairman's Factual Report

DCA13MA120

A. ACCIDENT

Operator:	Asiana Airlines
Location:	San Francisco, California
Date:	July 6, 2013
Time:	1128 Pacific daylight time[1]
Airplane:	Boeing 777-200ER, registration: HL7742

B. OPERATIONS / HUMAN PERFORMANCE GROUP

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[1]All times are based on a 24-hour clock. Time of the accident is approximate.

Lee Dae Young
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C. SUMMARY

On July 6, 2013 at 11:28 am Pacific daylight time, a Boeing 777, registration HL7742, operated by Asiana Airlines as flight 214, struck the seawall short of runway 28L at San Francisco International Airport. The airplane was destroyed by impact forces and fire. Three of the 291 passengers were fatally injured. The flight was a regularly scheduled passenger flight from Incheon International Airport, Seoul, Korea, and was operated under the provisions of 14 Code of Federal Regulations Part 129. Visual meteorological conditions prevailed at the time of the accident.

D. DETAILS OF THE INVESTIGATION

Operations / Human Performance Group activities are outlined in the Operations Group Chairman's Factual Report. The Human Performance Group Chairman's Factual Report contains additional documentation relevant to flightcrew pre-accident activities and health; company policies involving post-accident toxicological testing, flight and duty time limits, crew resource management (CRM) training, safety management, and use of automation; as well as B777 autoflight system design logic.

E. FACTUAL INFORMATION

1.0 Flight Crew Information

1.1 The Pilot Flying (PF)

The pilot flying (PF), age 45, was based at Incheon International Airport (ICN), married, and lived in Seoul with his wife and two teenage children. He reported that he needed 6 to 8 hours of sleep per night to feel rested, but slept from about 2300 to 0600 or 0700 each night when off duty for an extended period. He reported no recent stressors in his personal life. He stated, however, that life was generally stressful and that performing B777 operating experience (OE) flights was stressful.

1.1.1 The PF's Pre-accident Activities

The PF's pre-accident activities were documented through interviews, company records, and personal electronic device (PED) records.[2] His sleep opportunities are summarized in Table 1.

[2] For more information, see Attachment 1 to the Operational Factors Group Chairman's Factual Report and the Portable Computing Devices Specialist's Factual Report.

Table 1. The PF's self-reported sleep.

Date	Went to Bed	Woke Up	Sleep Opportunity
July 3-4	Could not recall	Could not recall	Unknown
July 4-5	Could not recall	Could not recall	Unknown
July 5-6	2200 or 2300*	0700*	8 to 9 hours
July 6 (Flight)*	2108	2308	About 2 hours

Note: *Times shown are Korea time, based on a 24-hour clock.

On Thursday, July 4, the PF woke at an unknown time. He served as PF on a roundtrip from ICN to Narita and back to ICN. He recalled departing ICN about 1500, returning to ICN about 2200, and arriving at his residence about midnight. He could not recall when he fell asleep.

On Friday, July 5, the PF woke at an unknown time. He was off duty and engaged in routine activities at home. He went to sleep about 2200 or 2300 and slept 8 or more hours.

On Saturday, July 6, the PF woke about 0700. He felt rested. He went jogging, returned about 0800, and ate breakfast. He took a bus to ICN about 0930. He arrived about 1030 and began preparing for Flight 214. The official show time was 1510, but he met his instructor (the pilot monitoring or PM) about 1440 and they began briefing for the flight. The PF had a cup of coffee when he arrived at the airplane. Pushback occurred about 1630, and the flight took off at 1653.[3] The departure was normal.

The PF was in the cockpit for the first 4 hours 15 minutes of flight. After reaching the initial cruising altitude, he ate a crew meal and drank a second cup of coffee. At 2108 he left the cockpit, went to a business class seat that reclined flat, and began a 5-hour rest break. He recalled being asleep for the first 2 hours of the break (about 2108 to 2308) and half-asleep for the rest of it. He recalled feeling tired but finding it difficult to sleep. Near the end of the break, he ate a small meal and drank a third cup of coffee.

The PF was scheduled to re-enter the cockpit at 0208 but returned about 0138 instead. He decided to do this because it was a training flight. The PM joined him at the scheduled time and they resumed control of the flight. The PF recalled feeling excited when he returned to the cockpit because he had not flown into SFO in 10 years. However, he recalled feeling stressed when he learned that the runway 28L glideslope was out of service. He was concerned about his ability to conduct a stable visual approach without the electronic glideslope.

1.1.2 The PF's Health

The PF's most recent first class medical certificate, issued by the Republic of Korea Ministry of Land, Transport and Maritime Affairs, was dated September 14, 2012, and bore no limitations. In a post-accident interview, the PF said his health was good. He did not smoke, exercised regularly, and tried to maintain a healthy diet. He reported no chronic medical

[3] For a more detailed history of flight, see the Operational Factors Group Chairman's Factual Report.

conditions and said he had experienced no symptoms of illness during Flight 214. He reported no use of medications in the 72 hours before accident. He reported his last use of alcohol as 250 milliliters of beer consumed July 5, 2013. His luggage was recovered from the wreckage, inventoried, and found to contain no medications. The KARAIB collected scalp hair samples from the PF on August 4, 2013 and submitted them to the Korean National Forensic Service for toxicological tests which found no evidence of drug use.[4]

1.2 The Pilot Monitoring (PM)

The pilot monitoring (PM), age 49, was based at ICN, married, and lived in Seoul with his wife and teenage son. He reported needing 6 to 7 hours of sleep per night to feel rested and said he typically slept 7 hours per night when off duty for an extended period. He reported no recent personal stressors.

1.2.1 The PM's Pre-accident Activities

The PM's pre-accident activities were documented through interviews, company records, and PED records.[5] His sleep opportunities are summarized below.

Table 2. The PM's self-reported sleep.

Date	Went to Bed	Woke Up	Sleep Opportunity
July 3-4	2400	0600	6 hours
July 4-5	2400	0700 or 0800	7 or 8 hours
July 5-6	2400	0800	8 hours
July 6	Mid-morning	Mid-morning	15 minutes
July 6	Mid-afternoon	Mid-afternoon	20 minutes
July 6-7 (Flight)*	2128	0028	3 hours

*Note: Times are shown in Korea time, based on a 24-hour clock. Although the accident occurred on July 6 in San Francisco, some of the pilot's last sleep period occurred on July 7 Korea Time.

On Thursday, July 4, the PM woke at 0600 and went to Asiana Airlines training facility in Seoul. He participated in joint crew resource management (JCRM) training from 0800 to 1600, returned home about 1700, and went to sleep about midnight.

On Friday, July 5, the PM woke about 0700 or 0800. He spent the day engaging in routine activities at home. He picked up his wife from a class about 2200 and went to sleep about midnight. He recalled that his quality of sleep was okay.

[4] Gas chromatography / mass spectrometry, gas chromatography / tandem mass spectrometry, and liquid chromatography / tandem mass spectrometry methods were used to look for evidence of 47 different substances, including amphetamine-type stimulants, cannabinoids, opioids, cocaine, and benzodiazepines.
[5] For more information, see Attachment 1 to the Operational Factors Group Chairman's Factual Report and the Portable Computing Devices Specialist's Factual Report.

On Saturday, July 6, the PM woke about 0800. He ate breakfast, visited with family, and watched television. He recalled taking a 15-minute nap while watching television. He reported leaving home at 1310 or 1315 and taking a 1330 bus to the airport. He reported napping for 20 minutes on the bus. He recalled arriving at the airport about 1420 and changing into his uniform. He recalled feeling rested as he went on duty. He began briefing Flight 214 with the PF about 1440.

The flight took off at 1653. He was in the cockpit for the first 4 hours 15 minutes of the flight. During this time he ate a crew meal and drank a cup of coffee. He was relieved by the relief captain about 2108 and took a rest break. He went to a business class seat that reclined flat and slept from about 2128 to 0028. When he woke, he ate some soup, drank a second cup of coffee, and watched movies. He returned to the cockpit about 0208 feeling "normal" as he and the PF resumed control of the flight.

1.2.2 The PM's Health

The PM's most recent first class medical certificate, dated September 5, 2012, and issued by the Republic of Korea Ministry of Land, Transport and Maritime Affairs, bore no limitations. In a post-accident interview, the PM stated that he had hypertension but that otherwise his health was okay. He did not smoke. He reported experiencing no symptoms of illness during Flight 214. He was taking a medication called "amochai tan" on a daily basis to control hypertension and a daily dietary supplement called "milk thistle." He reported no other use of medications in the 72 hours before the accident. His luggage was recovered from the wreckage, inventoried, and found to contain a bottle of labeled "amlodipine camsylate and losartan potassium (5mg/100mg)" which contained orange pills marked "AT2."[6] The PM said he could not remember his last use of alcohol because he rarely drank. The KARAIB collected hair samples from the PM's scalp August 4, 2013, and submitted them to the Korean National Forensic Service for toxicological tests which found no evidence of drug use.[7]

1.3 The Relief First Officer (FO)

The relief first officer (FO), age 40, was based at ICN and lived in Seoul. He was married and lived near Seoul with his wife and teenage daughter. He said he normally went to sleep between 0200 and 0300 and woke between 0930 and 1000, sleeping 6.5 to 8 hours. He reported no recent personal stressors.

1.3.1 The FO's Preaccident Activities

The FO's pre-accident activities were documented through interviews and company records.[8] His sleep opportunities are summarized below.

[6] Amlodipine camsylate and losartan potassium is a prescription medication used for treatment of hypertension.
[7] Gas chromatography / mass spectrometry, gas chromatography / tandem mass spectrometry, and liquid chromatography / tandem mass spectrometry methods were used to look for evidence of 47 different substances, including amphetamine-type stimulants, cannabinoids, opioids, cocaine, and benzodiazepines.
[8] For more information, see Attachment 1 to the Operational Factors Group Chairman's Factual Report and the Portable Computing Devices Specialist's Factual Report.

Table 3. The FO's self-reported sleep.

Date	Went to Bed	Woke Up	Sleep Opportunity
July 4	0200 to 0300	0930 to 1000	6.5 to 8 hours
July 5	0200 to 0300	0930 to 1000	6.5 to 8 hours
July 6	0200	1130	9.5 hours
July 6 (Flight)	1908	2108	2 hours
July 7 (Flight)*	0223	0243	20 minutes

*Note: Times are shown in Korea time, based on a 24-hour clock. Although the accident occurred on July 6 in San Francisco, some of the pilot's last sleep period occurred on July 7 in Korea Time.

On Thursday, July 4, the FO was off duty. He went to sleep between 0200 and 0300 and woke between 0930 and 1000. He reported spending the day at home reading books.

On Friday, July 5, the FO was off duty. He went to sleep between 0200 and 0300 and woke between 0930 and 1000. He was home until 1600, when he picked his daughter up from school and ate dinner at a restaurant. He returned home at 2000 and read books.

On Saturday, July 6, the FO went to sleep about 0200 and woke about 1130. He recalled that his quality of sleep was good. He ate lunch and left home at 1250 to catch a 1310 bus to the airport. He arrived at the airport at 1420 feeling okay.

Flight 214 took off at 1653. During the initial portion of the flight, the FO rested in a business class seat that reclined flat. He ate dinner and drank a cup of coffee about 2 hours into the flight, and then took what he described as a good-quality 2-hour nap. At 2108 he went to the cockpit and began operating the flight with the reserve captain. While he was in the cockpit, he consumed four more cups of coffee and had a snack. At 0208, he was relieved by the PM and returned to his seat in business class. He slept from about 0223 until 0243. When he woke, he felt tired. He tried to make himself feel more alert by going to the restroom and performing stretches. When he returned to the cockpit for the arrival at SFO, the airplane was at 11,000 feet MSL. He sat down in the center jump seat and prepared to monitor the approach.

1.3.2 The FO's Health

According to Asiana records, the FO's most recent first class medical certificate, issued by the Republic of Korea Ministry of Land, Transport and Maritime Affairs, was dated July 4, 2013, and it bore no limitations.[9] In a post-accident interview, the FO stated that his health was good. He stated that he had not taken any medications in the 72 hours before the accident except a supplement containing bilberry extract for good vision. His reported his last use of alcohol as a glass of wine consumed the evening of July 4, 2013. He stated that he did not experience any symptoms of illness during the flight. After the accident, he was transported to a hospital where

[9] According to Asiana Airlines, although the FO's most recent medical certificate was dated July 4, 2013, his most recent medical exam was conducted July 2, 2013.

blood and urine samples were collected. Toxicological testing of the samples at the FAA's Civil Aerospace Medical Institute detected no evidence of alcohol or performance-impairing drugs.[10]

2.0 Organizational Information

For an overview of Asiana Airlines history, organization, fleet composition, and pilot workforce, see the Operational Factors Group Chairman's Factual Report.

2.1 Company Drug and Alcohol Testing Policy

The Asiana Flight Operations Manual (FOM), paragraph 12.17.5, "Drug and alcohol test," dated May 1, 2006, stated:

a. Company (medical team) must conduct alcohol or psychoactive drug test on the survivors of the accident including not only the crew members who are directly related to the accident but also who does not have direct bearing on the accident.
b. The Authorities (or CAA in relevant nations) may require post-accident drug and alcohol testing of the flight crew.
c. All crew members are prohibited from using drugs or alcohol if the accident was drug or alcohol related.
d. All crew members involved in an accident must be available for a test.

2.2 Flight and Duty Time

According to Korean Flight Safety Regulations (FSRs), Section 8.140 and Appendix 8.4.9.3, flightcrews consisting of two captains and two additional pilots were limited to a maximum of 16 consecutive hours of flight time and 20 consecutive hours duty time. In addition, Appendix 8.4.9.4. stated that pilots were limited to 120 flight hours per 28 days and 1,000 flight hours per 365 days. The Asiana Airlines Flight Operations Manual, section 4.1.9.1. also limited four-pilot crews to 16 hours of flight time and 20 hours of duty time.

By the time of the accident, the PF and PM had accumulated 10 hours 35 minutes of flight time and 12 hours 48 minutes of duty time. The FO had accumulated 10 hours 35 minutes of flight time and 12 hours 18 minutes of duty time. Flight time, duty time and other rest-related parameters for the PF, PM, and FO are summarized in the table below.

[10] Specimens were screened using immunoassay and chromatography to detect alcohol and a variety of legal and illegal drugs, including: amphetamines, opiates, marihuana, cocaine, phencyclidine, benzodiazepines, barbiturates, antidepressants, and antihistamines.

Table 4. Flight time, duty time, and other rest-related parameters for the PF, PM, and FO.

	Flight Time (Hours)	Duty Time (Hours)	Time Since Departing Residence (Hours)	Cumulative Reported Sleep in Last 24 Hours (Hours)	Reported Sleep Periods
Pilot Flying (PF)	10:35	12:48	17:58	5:32	2
Pilot Monitoring (PM)	10:35	12:48	14:13	8:07	4
First Officer (FO)	10:35	12:18	12:55	10:22	3

2.3 Crew Resource Management / Threat and Error Management Training

Korean FSRs (Appendix Section 8.3.4.4 and 8.3.4.13) required all air carriers to provide initial and recurrent CRM training to all flight crewmembers. This requirement was instituted in 2002. Training was required to address the following topics:

1. Communication systems
2. Factors that affect communication
3. Obstacles to communication
4. How to listen
5. Decision-making
6. Effective conclusions law
7. Development of public communication
8. Inquiry, advocacy, and assertiveness
9. Self-reflection of the crew
10. Conflict resolution methods
11. Team composition and appropriate ways to maintain it
12. Leadership training
13. Interpersonal skills
14. Workload management
15. Situational awareness
16. Ways to achieve this goal
17. Workload distribution
18. Avoiding distractions
19. Personal factors
20. Reducing Stress

Asiana first began providing CRM training to pilots in 1994. The company introduced line-oriented flight training (LOFT) in 1996 and CRM “refresher” training in 1999. CRM for foreign crewmembers and joint CRM (JCRM) for cabin and flight crewmembers courses were added in 2000. In 2009, the company created a human factors and CRM department within the flight crew training team and, a year later, this department introduced new CRM training

courseware based on a threat and error management (TEM) model. In March 2011 and April 2013, the company hosted CRM/TEM seminars. At the time of the accident, Asiana required pilots to complete initial CRM, CRM refresher, JCRM , LOFT, upgrade CRM, and instructor designation CRM training as shown in Table 5.

Table 5. Asiana CRM pilot training requirements.

Requirement Classification	Initial	CRM Refresher	LOFT	JCRM	Upgrade Training	Instructor Designation
Initial Qualification	21 hours	7 hours	4 hours	7 hours	7 hours	6 hours
Recurrent	2 hours		Once per year	Once every 3 years		

These courses covered the topics shown in Table 6.

Table 6. Topics covered in Asiana CRM training courses.

	Initial	Refresher	Recurrent	Captain Upgrade	Instructor Designation	JCRM
CRM introduction	X					
Culture	X					
Decision making	X					
Communication	X			X	X	
Teamwork	X			X	X	
Situation awareness	X	X		X	X	
Leadership	X	X		X	X	
Automation	X					
Checklists and briefings	X					
Stress and fatigue management	X	X		X	X	X
Threat and error management (TEM)	X	X		X	X	X
Monitoring and workload	X	X		X	X	
Topic selected from initial training			X			
Case study and discussion			X			X

Emergency escape / SIM experience						X
Understanding each other's regulations						X
Other safety and threat factors						X

In late 2012/early 2013, Asiana introduced a voluntary "Family CRM" training course for flightcrew and their family members. The focus of this course was on how communications and relationships at home could affect flightcrew performance and safety. In 2012, the special topic from initial training that was highlighted during recurrent training was threat and error management (TEM). In 2013, the special topic was monitoring and workload management. Table 7 contains dates of the most recent CRM training received by each of the accident flightcrew members as provided by Asiana.

Table 7. Most recent crew resource management training received by the flightcrew.

Flightcrew Member	Initial	Recurrent	JCRM	Instructor Designation
Pilot Flying (PF)	1/16/1998	4/30/2013	4/19/2013	5/19/2010
Pilot Monitoring (PM)	5/29/1998	4/30/2013	7/4/2013	5/16/2013
Relief First Officer (FO)	9/3/2008	4/30/2013	12/17/2008	N/A

Note: Dates are presented in month/day/year format.

2.4 Safety Management System

In accordance with International Civil Aviation Organization (ICAO) guidelines,[11] Korean aviation law required air carriers to establish a government-approved safety management system (SMS).[12] Asiana Airlines established an SMS on January 1, 2008, before this requirement was enacted. The company's SMS was led by a vice president, safety and security, who reported directly to the company's CEO and company safety review board. The vice president, safety and security, supervised a general manager who oversaw 23 personnel in four groups: a flight safety group (11 personnel), ground safety group (7 personnel), safety planning group (3 personnel), and education/support group (2 personnel). Safety actions identified by the SMS team were carried out by safety managers in flight crew quality assurance, maintenance quality assurance, cargo service, cabin support, airport service, and operation control and support.

[11] ICAO Annex 6, Section 3.3. Safety Management.
[12] Korean Aviation Safety Act, Article 49 (Aviation Safety Program).

The goal of the SMS was to "maintain a state of zero accidents." Safety of operations was tracked by monitoring incident occurrence rates, including events such as EGPWS warnings. The safety manager for flight crew quality assurance was responsible for implementing SMS program functions in flight operations.

The company had operated a flight operations quality assurance (FOQA) program since 1994. The SMS team maintained a mandatory safety reporting system described as a "safety occurrence report" and a voluntary system described as a "hazard report." The company described both reporting systems as being "penalty free." Safety reports were investigated by the appropriate safety division and reviewed by the SMS team, and findings were used for hazard identification and risk management.

Asiana underwent periodic safety audits by an independent auditor.[13] The purpose of these audits was to assist with hazard identification, ensure sound operation of the company's SMS, and to ensure that approved procedures and legal requirements were being complied with. The company also performed annual internal audits of its cargo division, maintenance and engineering division, operational control center and flight operations division, cabin service division, and airport service division.

Asiana maintained an SMS manual and provided SMS training covering SMS concepts and procedures to SMS team members and company managers. The company communicated safety information to employees by analyzing safety information from internal and external sources and disseminating information to related staff. This was accomplished through the use of safety memos, safety directives, and other means.

In May 2012, Asiana began developing a voluntary fatigue risk management system (FRMS) using guidelines contained in International Civil Aviation Organization (ICAO) Document 9966, *FRMS Manual for Regulators*. The company began holding monthly FRMS task force meetings in June 2012 and safety department staff established an FRMS development plan in September 2012. Safety department staff attended an ICAO Asia-Pacific FRMS seminar in April 2013. The company was still in the planning phase of FRMS development at the time of the accident.

2.5 Asiana Procedure for Flightcrew Mode Selections and Related Callouts

Company standard operating procedures regarding mode selections and callouts were contained in the company's B777 Pilot Operating Manual (POM), excerpts of which are shown below. [14]

2.1.4 Crew duties

g. The mode control panel is the PF's responsibility. When flying manually, the PF directs the PM to make the changes on the mode control panel.

[13] Asiana Airlines was first registered as an International Air Transport Association (IATA) Operational Safety Audit (IOSA) operator on August 27, 2004. The last IOSA renewal audit was performed on the carrier April 2-6, 2012.

[14] For additional information on Asiana's flightcrew procedures pertaining to use of the B777 automatic flight control system, see section 5.3.1 of the Operational Factors Group Chairman's Factual Report.

2.1.7 Standard Callouts & Response Procedures
2.1.7.1. Concept
a. Crew Coordination Concept
2) Crews should perform as reciprocal back up and as a monitor.
a) Pilot who is in charge of "flight mode change" must call out his accomplishment of mode change and the other pilot responses a confirmation.
b) When PM does not perform PF's order, PF should perform it him/herself.
…
b. Importance
1) Safety operation will be guaranteed by sincerity and correct Standard Callout and Response.
2) Every Callout & Response should be made clearly and loud enough to understand without doubt.
3) Every callout should be accompanied with response.
…
6) Except silence checklist items, callout every action and proper respond is necessary.
7) PM calls out every FMA (Flight Mode Annunciator) mode change. ex) SPD, THR, LNAV, VNAV, FLCH SPD, ALT etc.

2.1.7.3 The Usage of Term
b. Callout & Response when accomplishment and confirmation
1) All accomplishment items
Pilot who operates items calls out what he/she has done, the other pilot responses "Checked" after confirmation.

2.6 Asiana Procedure for Monitoring by the PM During an Approach

The Asiana POM contained the following guidance with respect to monitoring duties of the PM during an approach:[15]

2.13 Approach Procedure
2.13.1 PF/ PM's Duties
2.13.1.2 PM (Pilot Monitoring)'s Duties
a. All Approaches
1) Active Standard Callout
2) Cross check all primary instrument and raw Data.
3) Monitor any display of warning/caution flags or deviation from the intended flight path and callout to PF.
4) Monitor speed and descent rate until touchdown.

[15] For additional information on Asiana guidance related to flightcrew monitoring, see section 5.3.4 and 5.3.5 of the Operational Factors Group Chairman's Factual Report.

2.7 Asiana Procedures for Missed Approach / Go-Around Decision and Related Callouts

The Asiana POM contained, in part, the following procedures addressing missed approach / go around and related callouts.[16]

2.13 Approach Procedure
2.13.1 PF/ PM's Duties
2.13.1.2 PM (Pilot Monitoring)'s Duties
a. All Approaches
6) When A/C is Un-Stabilized or safe landing is not assured, advice to PF to make a missed approach.

2.13.2 CRM

2.13.2.2 Deviation Callout
a. When speed, glideslope, localizer, sink rate, thrust, or visual guidance is out of approach limitation, PM should call it out clearly.
…
c. If a missed approach is required, PM should advise missed approach (GO AROUND call out)

2.8 Asiana Pilot Training on Select Aspects of AT Function

An Asiana ground school training module titled "Automatic Flight System" was presented to the PF during B777 transition training. It described autothrottle function during FLCH descent:

- For descent – activates in THR mode, followed by HOLD if the thrust levers reach idle

Descent:
A/T / / PITCH FMA
THR / / FLCH SPD
→ HOLD / /
(When Altitude Captured)
SPD / / ALT

Although not included on any slides, an Asiana B777 ground school instructor provided a written statement indicating that during a B777 ground school class attended by the PF he explained that the AT would sometimes remain in HOLD mode after the AP was disconnected and airspeed could drop. He said he advised students that this could occur during a high-energy descent in FLCH mode and that if they encountered this situation they should change the AFDS pitch mode to V/S or VNAV. An Asiana pilot who was in this instructor's class with the PF

[16] For additional information on Asiana's procedures pertaining to missed approach / go around, see section 5.3.3 and 5.3.5 of the Operational Factors Group Chairman's Factual Report.

confirmed that the instructor had provided this information. The same student stated that a second instructor had provided the same information during another B777 ground school class attended by the PF. He said the second instructor had also advised students that they should not use FLCH to descend after crossing the final approach fix.

The "Automatic Flight System" training module stated the following with respect to flight envelope protection:

> There are three forms of flight envelope protection in the autopilot:
> - Stall protection
> - Overspeed protection
> - Roll envelope and bank angle protection
>
> DOES THE AUTOPILOT NEED TO BE ENGAGED TO HAVE FLIGHT ENVELOPE PROTECTION? NO
> (Demo in SIM)

A subsequent slide stated the following additional information.

> An AUTOPILOT caution message and roll or pitch mode failures alert the pilot if the envelope is exceeded and the autopilot prevents further envelope violations.
>
> Refer to the Flight Controls chapter for a description of flight envelope protection

An Asiana training module titled "B777 Flight Controls – Recurrent Training" that was in use at the time of the accident contained the following additional information about stall protection:

> Stall Protection Feature
> - Reduces the possibility of reaching stick shaker
> - No trim below minimum maneuvering speed
> - Slow speed requires continuous back pressure
> - Autothrottle engaged automatically (if armed)

Neither the "Automatic Flight System" training module nor the "B777 Flight Controls – Recurrent Training" module slides indicated that the low speed protection function provided by the AT would not activate if the AT was in HOLD mode. However, notes in the B777 FCOM (section 4.20.9) stated the following:

> Note: When the pitch mode is FLCH or TOGA, or the airplane is below 400 feet above the airport on takeoff, or below 100 feet radio altitude on approach, the autothrottle will not automatically activate.
> …
> Note: During a descent in VNAV SPD, the autothrottle may activate in HOLD mode and will not support stall protection. [17]

[17] For additional information about the functioning of the AT system, see sections 4.2.1.5.1. and 4.3.1. of the

2.9 Asiana Pilot Statements About AFDS/AT Design Logic

The PF and several other Asiana pilots and instructors provided statements about B777 AFDS/AT design logic.[18] The PF stated that the B777 AT system would always maintain the selected airspeed as long as the AT was on. He said that if a pilot overrode the throttles manually, the autothrottle would resume controlling airspeed when the pilot let go of the throttles. He stated that it was irrelevant whether he had pushed the FLCH button immediately before disconnecting the AP during the accident approach because he was in manual flight and the AT was always working. He thought the AT should have automatically advanced the throttle levers upon reaching the MCP selected airspeed during the accident approach and he did not understand why that did not occur. Furthermore, he thought the AT system should have automatically transitioned to TOGA when the airplane reached minimum airspeed. In that respect, he believed that the B777 AT functionality was similar to alpha floor protection on the Airbus A320/321. Asked how confident he was in his understanding of the B777 autoflight system, he said he had followed the Asiana training program but he was not confident in his understanding and he thought he needed to study more.

A B777 OE instructor captain who conducted an OE instructor check flight with the PM was asked to predict how the B777 autoflight system would behave if the FLCH pushbutton was selected while descending through 2,000 feet MSL in vertical speed (V/S) mode with the AP on and the MCP altitude set to 3,000 feet. He said the throttle levers would advance and the airplane would try to climb. Asked what mode the AT would be in if the pilot manually pulled the throttle levers back, he said the AT would remain in SPD mode and the throttle levers would advance after the pilot released them. Three additional Asiana pilots were asked what would happen in this same scenario if a pilot pulled the thrust levers back manually and then disconnected the AP. A B777 OE instructor captain who had conducted an OE training flight with the PM said he did not know what thrust mode the AT would be in after this sequence of actions. Two B777 OE instructor captains who had conducted OE training flights with the PF said that the AT would transition to HOLD mode and remain there until a different pitch mode was selected by the pilot.

The Asiana B777 ground school instructor (referenced in section 2.8 of this report) who taught the PF's B777 flight controls class said he had encountered "anomalous" AT system behavior during three separate high-energy visual approaches, one at Seattle-Tacoma International Airport, and two at SFO. He described this behavior as follows:

> …the altitude was 8,000… [the airplane was] too high for a normal landing, so I used FLCH mode to descend, with speed brake up and landing gear down. At 2,000 feet, I realized that the altitude was still too high and turned off both flight directors and switched to manual flight. During the approach to the runway, the airspeed was falling close to target airspeed but the autothrottle was in idle state and did not respond. I let the First Officer know of this situation and when the airspeed was 10 knots below target airspeed, I turned off the autothrottle and manually pushed the throttle and had an uneventful landing. However, I was surprised that the autothrottle did not maintain the selected target airspeed.

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[18] For details, see Attachment 1 to the Operational Factors Group Chairman's Factual Report.

> After the flight, I examined the "Flight Control" section of the Boeing Flight Crew Operations Manual ("Boeing FCOM") and was eventually able to find, with some difficulty, a single sentence "note" item on circumstances in which the autothrottle may not respond. I still felt this note was insufficient to explain what I had just experienced. Therefore, I did a further study of the "Autopilot" section of the Boeing FCOM and realized that in the circumstances I described above the autothrottle can be in a dormant state and the autothrottle will not function even if the target airspeed is reached. In my personal opinion, this is very important information that should be highlighted to pilots as a "warning" item and not merely as a "note" item in the Boeing FCOM.[19]

The ground school instructor said that as a result of his personal experience, he had made it a point to teach this aspect of the AT logic in B777 ground school classes.

The B777 chief pilot was asked if there were any conditions in which the B777 AT system would not provide low speed protection and he said the B777 AT system would not provide low speed protection in HOLD mode. He said this information was not included in Asiana's B777 pilot training curriculum but it was contained in the B777 FCOM and he thought Asiana B777 pilots were aware of it. When the same question was posed to three OE training captains (two of whom had conducted OE training flights with the PM and one of whom had conducted an OE flight with the PF), they said the AT system did not provide low speed protection in HOLD mode, however one said he had only learned that after the accident. A fourth OE instructor was asked the same question and said the AT system would not provide low speed protection if the AP and AT both failed. A Cambridge Communications Limited instructor pilot (who had been providing B777 simulator training to Asiana pilots since 2006 under a contract between Asiana and Boeing Training Services Korea LLC) was asked if he thought most pilots understood that the B777 AT system did not provide low speed protection in HOLD mode and he said he was not aware of that himself until Boeing provided an update to the B777 FCOM in 2012.[20]

3.0 Additional Information

3.1 FAA Certification Issue Involving AFDS/AT Design Logic

The FAA's primary project pilot for the Boeing B787 flight test certification program told investigators he had reported a certification issue involving a characteristic of the B787 AFDS/AT system that also existed on the B777.[21] He stated that his report was prompted by an event that occurred during a test flight he conducted in the B787 on August 30, 2010. He was flying the airplane from the left seat and descending from 10,000 to 3,000 feet in FLCH when a TCAS RA occurred. He responded by disconnecting the autopilot and manually leveling off. He subsequently noticed that the airspeed had decreased by 10 or 15 knots. As he watched, airspeed

[19] See Attachment 3 to the Operational Factors Group Chairman's Factual Report.
[20] Information provided by Boeing indicated that this 2012 update relocated a discussion of the AT's automatic activation feature from section 9.20, where it had been part of a larger discussion of stall protection features, to section 4.20, where it was included in a description of the AT.
[21] See interview with FAA test pilot Eugene Arnold in Attachment 1 to the operational factors group chairman's factual report.

continued to decrease until it was below the minimum maneuvering speed. At that point, he pushed up the throttle levers and recovered the airspeed.

The primary project pilot stated that he had about 1,000 hours of flight experience in Boeing airplanes, including about 500 hours in the B777, at the time of the incident, and the AT system had not functioned the way he expected during this incident. As a result, he had a conversation with Boeing about AT functioning and wakeup logic. He said Boeing advised him that the B787 AFDS/AT logic was very similar to the B777, B767, and B747 (which had been previously found to comply with FAA certification requirements). Nevertheless, the primary project pilot thought the system behavior was "less than desirable" and could be improved. As a result, he drafted an FAA Flight Test Response Item (RI) Report titled, "Autothrottle does not wake up when in Thrust Hold mode." This report, known as "RI-12" described the issue as follows: "When in a descent such as FLCH with autothrottle in THR HOLD mode, and the descent has to be manually interrupted for something such as traffic alert, the autothrottle will stay in THR HOLD mode and will not wake up as it does when you capture the original altitude. The speed will decrease well past maneuvering speed."

According to the primary project a similar concern was voiced by the European Aviation Safety Agency (EASA) in a finding titled "Major Recommendation for Improvement #3." According to the primary project pilot, EASA described its concern as follows:

> The autothrottle wakeup feature has been considered by the certification team as a system improving significantly the safety of the aircraft to be certified. It protects the aircraft not only against stall but also against low energy states, anticipating on the stick shaker triggering. Unfortunately there are on the B787 (as well as some other previous Boeing models) at least two automation modes (FLCH in descent and VNAV speed in descent, with ATHR on HOLD) for which the autothrottle wakeup function is not operative and therefore does not protect the aircraft. Although the certification team accepts that this autothrottle wakeup feature is not required per certification requirements, these two exceptions look from a pilot's perspective as an inconsistency in the automation behavior of the airplane. Inconsistency in automation behavior has been in the past a strong contributor to aviation accidents. The manufacturer would enhance the safety of the product by avoiding exceptions in the autothrottle wakeup mode condition.

The primary project pilot stated that because the matter raised in RI-12 had been classified as a certification issue, rather than as a certification concern, recommendation, or note, it required closure prior to B787 type certification. The primary project pilot said RI-12 prompted discussions between FAA and Boeing. As a result, the FAA required Boeing to add a passage to the B787 Airplane Flight Manual (AFM) which stated, "During a descent in FLCH mode or VNAV SPD mode, the AT may activate in HOLD mode. When in HOLD mode, the AT will not wake up even during large deviations from target speed and does not support stall protection." This note was added to the B787 AFM in August 2011. The primary project pilot stated that a similar note was not added to the B777 AFM, which had been previously certified by the FAA.[22]

[22] For a description of the B777 FCOM's documentation of the AT's role in stall protection and its functioning in various AFDS/AT modes, see section 4.3.1 of the Operational Factors Group Chairman's Factual Report.